

# **Reactive Chemical Mechanical Polishing (RCMP) Process for Defect Free Sub-Surface Damage- Free Polishing of SiC Mirrors**

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**&**

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**EOC Pen State**

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*Program Monitor: Lawrence Mattson*

**Mirror Tech Days June 22, 2011**

**Non Proprietary Data**



# Outline

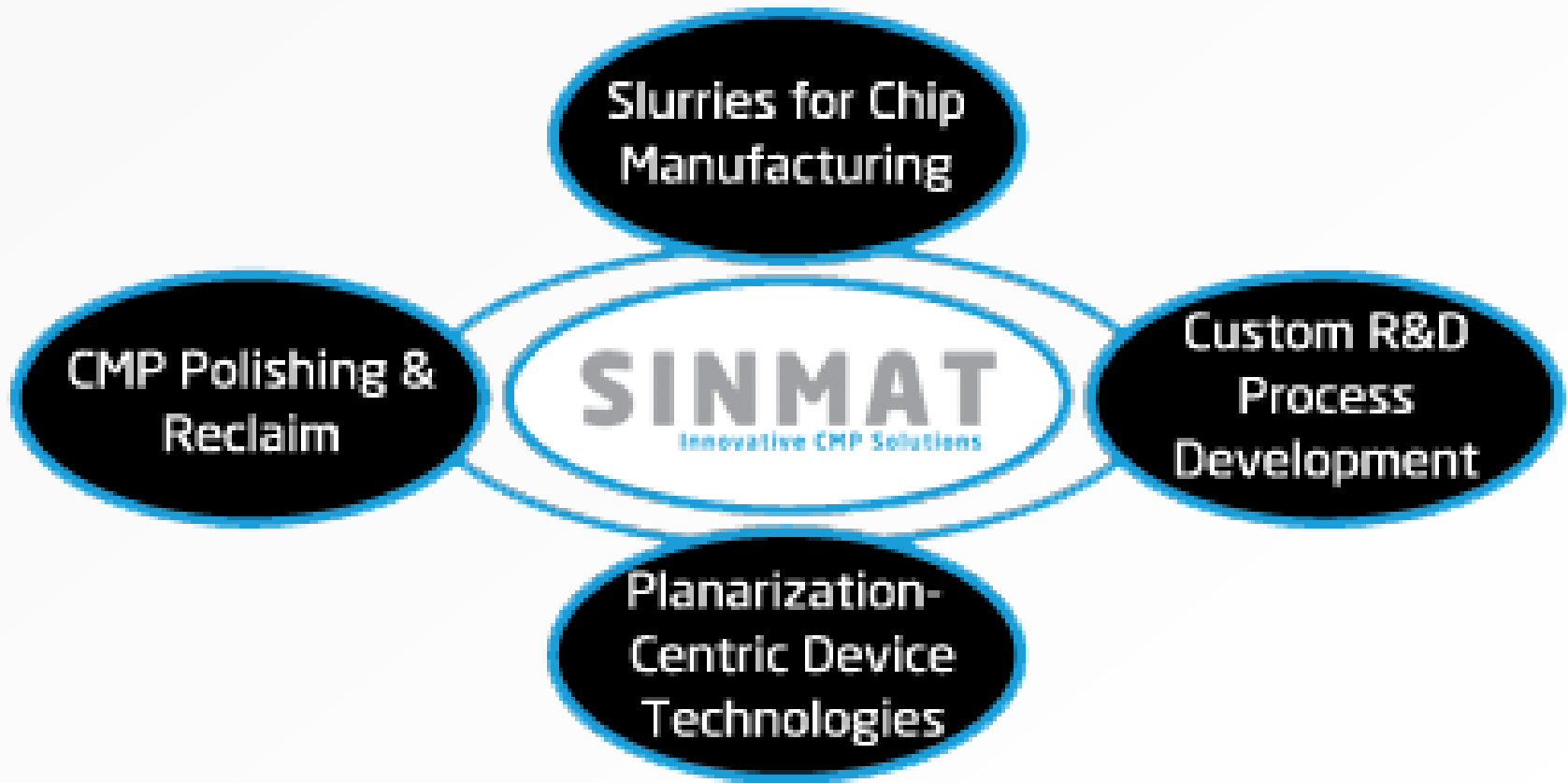
- **Introduction**
  - **Sinmat**
  - **SiC mirror**
- **Current Mirror Polishing**
  - **Current state of art**
- **Sinmat RCMP SiC Mirror Polishing Technology**
- **Polishing Results**
- **Conclusion**

# Sinmat

- University of Florida Spin-off
- Winner of four R&D 100 Awards 2004 & 2005, 2008, 2009
  - Top 100 most significant technologies of the year
- 12 licensed and 8 pending patents
- Employees : 23 and several consultants
- **Leading global supplier of SiC CMP polishing technology to the semiconductor chip industry**



# Sinmat – Core Strengths



## Development of Novel Planarization Technologies

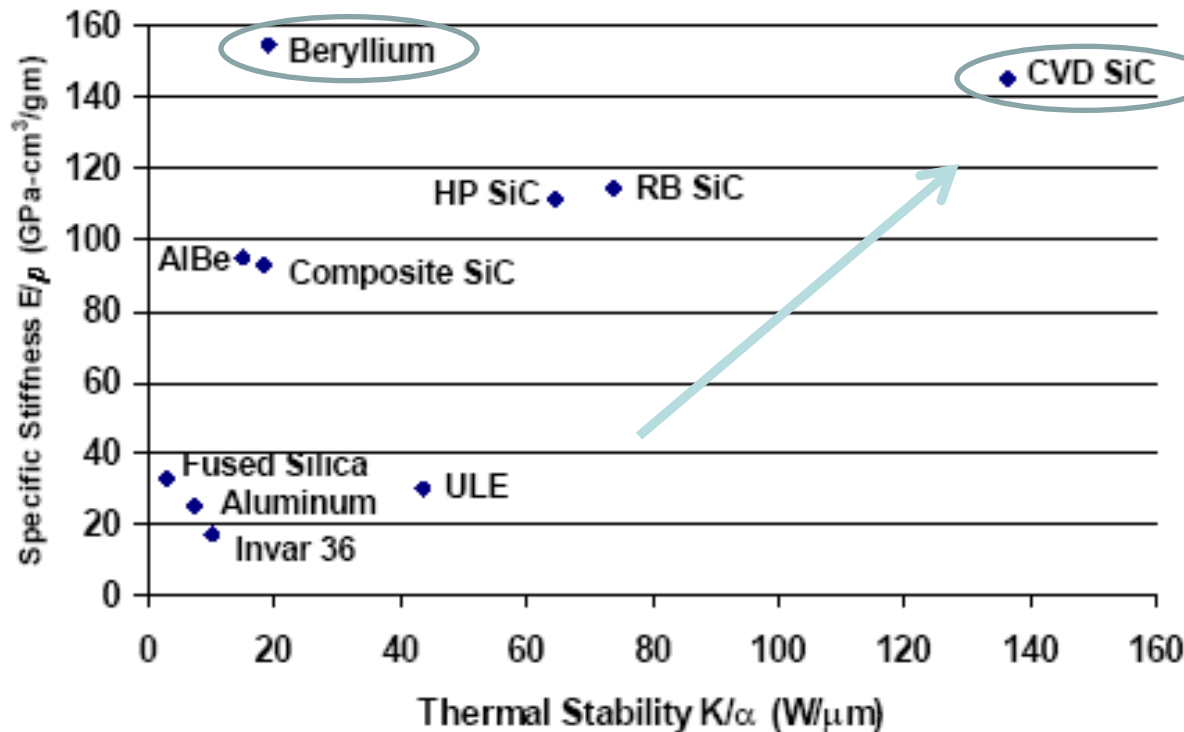
Non Proprietary Data



# Polishing Technologies

- 1) Silicon Carbide
- 2) Sapphire
- 3) Other oxides such as Spinel
- 4) Nitrides such as GaN/AlN
- 5) Diamond

# Mirror Materials



**SiC has a better combined specific stiffness and thermal stability than other optical materials which are desired for mirrors**

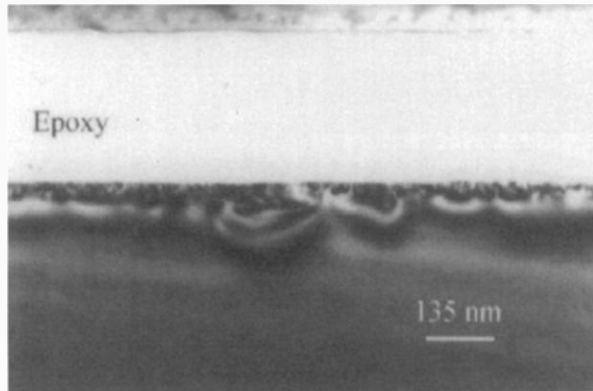
# **SiC Material Properties Creates Fabrication Challenges**

- **SiC is very hard & chemically inert**
- **Grain highlighting**
- **Very Low Removal Rates**
- **Poor Long Term Process Stability-  
Recirculating Slurry Process**
  - **Dispersion of large diamond particles**
  - **Poor figure correction capability**
- **Poor Control of Polishing selectivity with  
other materials e.g Silicon**

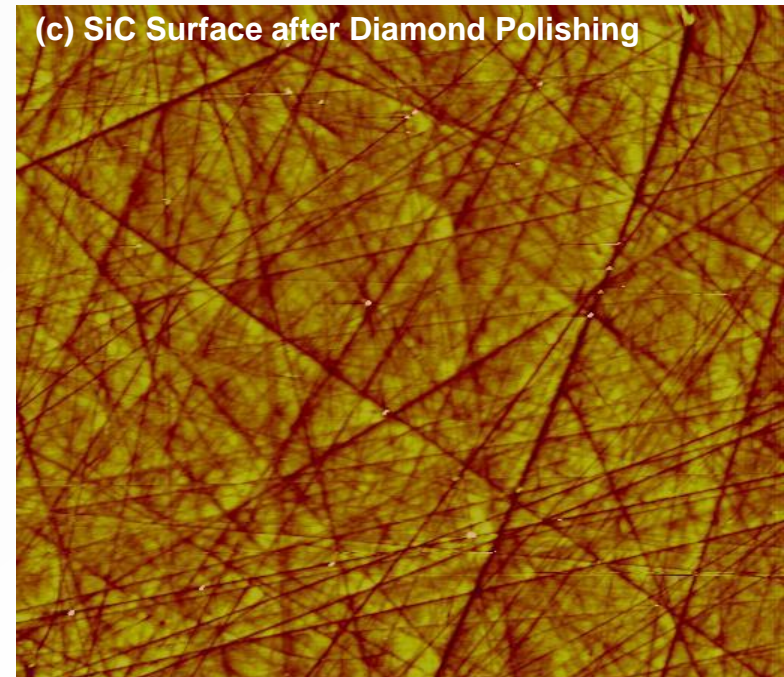


# Current State of the Art: Mechanical Polishing

- Uses Large Diamond Particles (250 nm – 5 micron)
- Mechanical Process creates damaged sub-surface layer (20 nm – 1500 nm)
- State of art Mirror Polishing results Scratches / Sub-surface damage



Damage zone > 1  $\mu\text{m}$



Need for a lower sub-surface damage Mechanical Polishing Process



# SiC Mirror Polishing Needs

**Need to develop a faster, cheaper, better, robust & flexible CMP process to polish polycrystalline SiC Mirrors**

- **Better**

- No scratches, atomically smooth; reduced sub-surface stresses and damage

- **Faster**

- >10X faster than current processes with fewer steps

- **Cheaper**

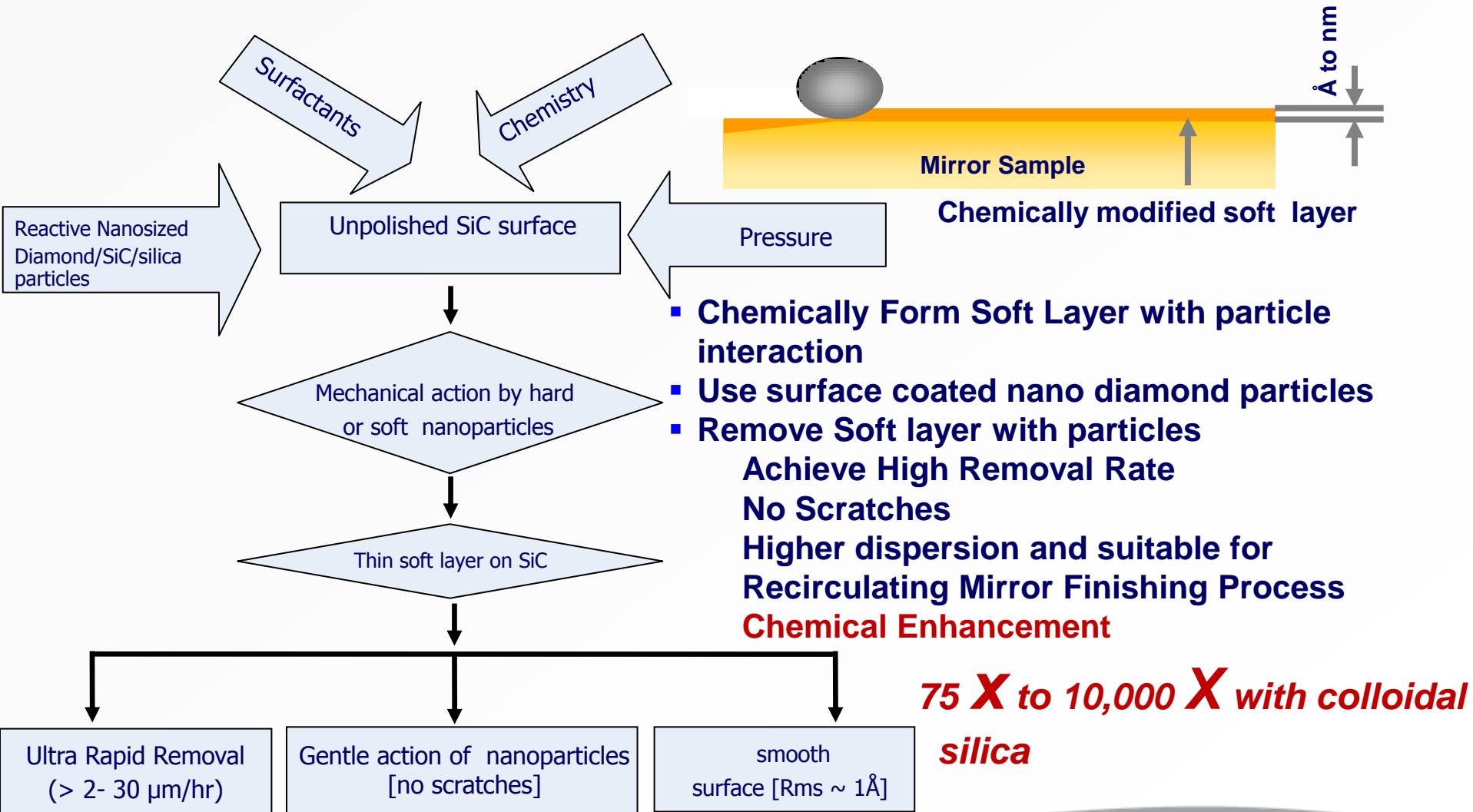
- < 50% of current costs

- **Robust , Scalable to aspherical and larger size mirrors and current equipment**

- Ultra-stable Recyclable finishing process

- **Tailoring of Polishing Selectivity with softer materials such as silicon**

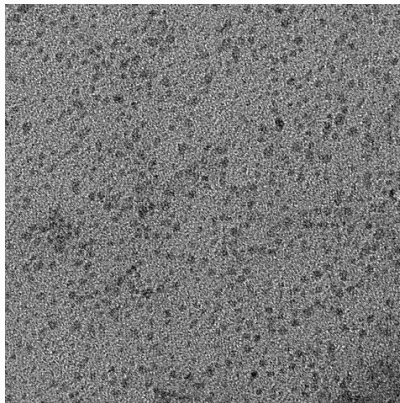
# RCMP Process-Technical Approach



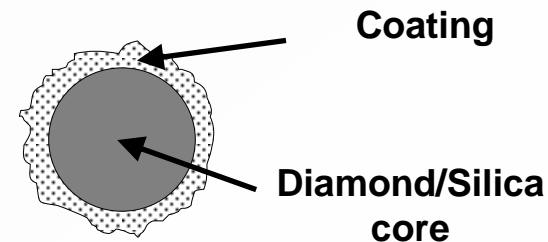
**Non Proprietary Data**

# Technical Approach (Continued)

- **Particles used**
  - Nano diamond (~5-10 nm)
  - Micro diamond (~100-250 nm)
  - Coated porous Silica particles
- Increase chemical activity of the diamond and silica with coating & surface modification
- Also enhancing the dispersion of diamond for recirculating CMP process



TEM of ultra nano diamond.



Functionalization of diamond

# **Sinmat's RCMP Mirror Technology Process**

- **Two step process**
  - **High Removal Rate (HRR) process**
  - **High Finish (HF) Process-**
  - **Both these slurries have excellent long term ( tens of hrs) polishing rate stability for High precision process**

# **Sinmat Polishing Process**

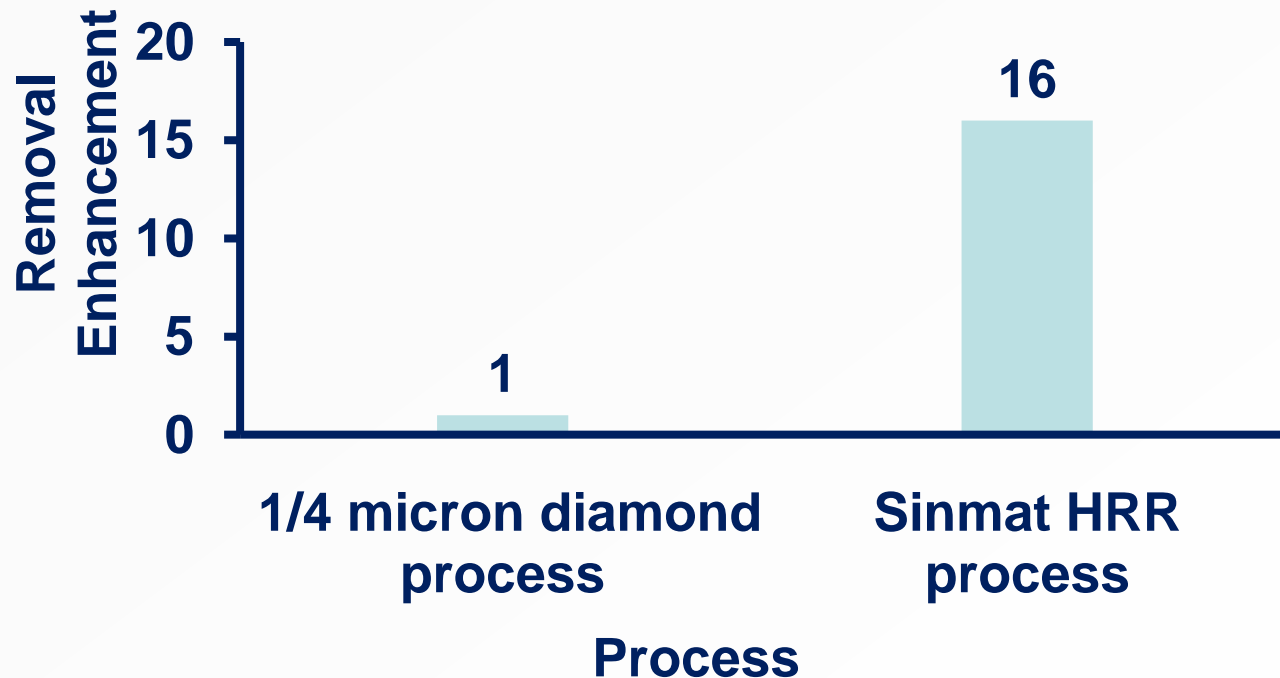
## ➤ **High Removal Rate (HRR) Process**

- **Rapid polishing and shape correction**
- **Reduce sub-surface damage**
- **May have grain highlighting**

## ➤ **High Finish (HF) Process**

- **Rapidly Achieve Angstrom level Smooth surfaces**

# Sinmat HRR Mirror Polishing Rate Comparison (Sinmat & EOC Penn State)

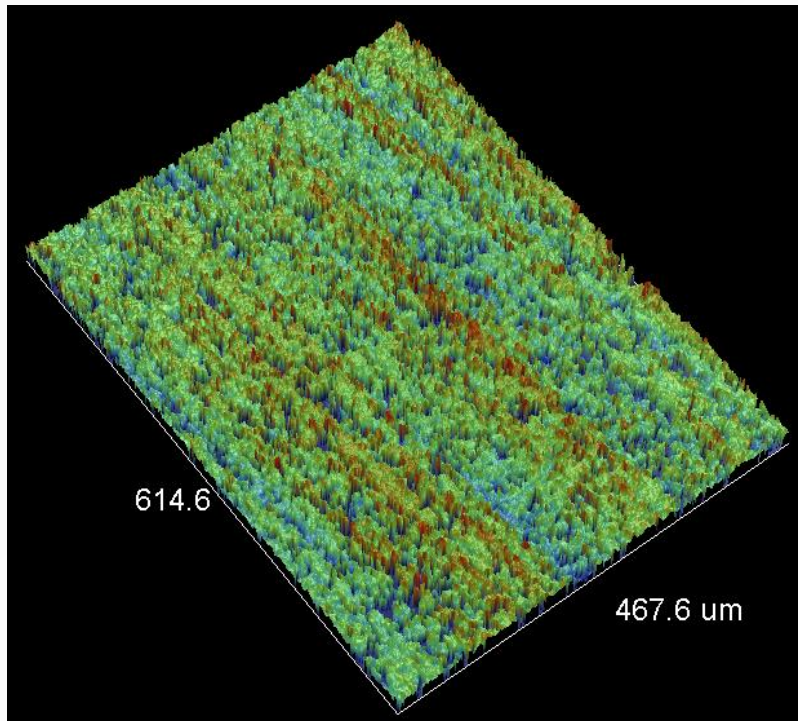


**10 -20 x Increase in removal rates**

**Non Proprietary Data**

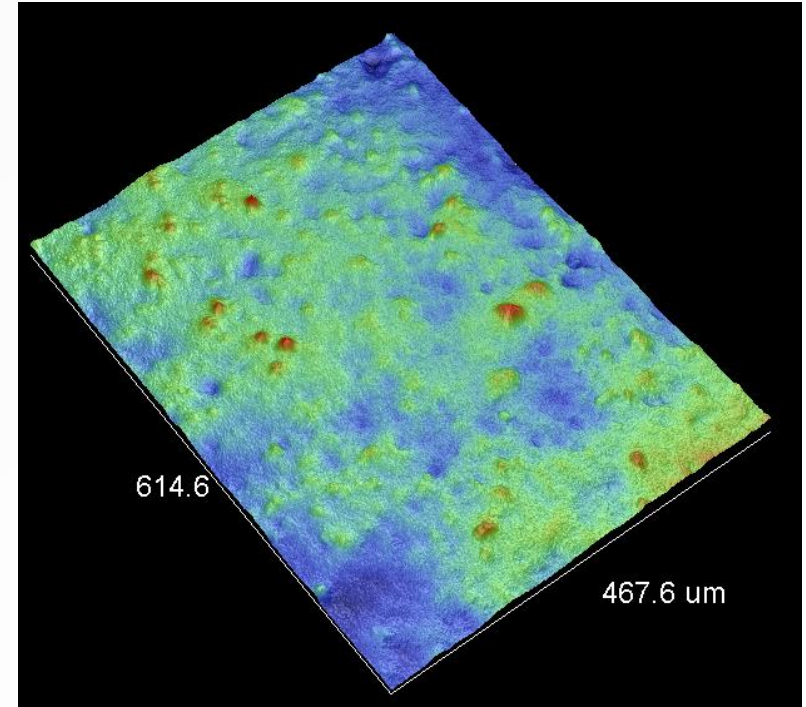
# Surface After HRR Polish Process Wyko (Sinmat)

As Received SiC mirror before Polish



Ra 250nm

Mirror: After Sinmat polish



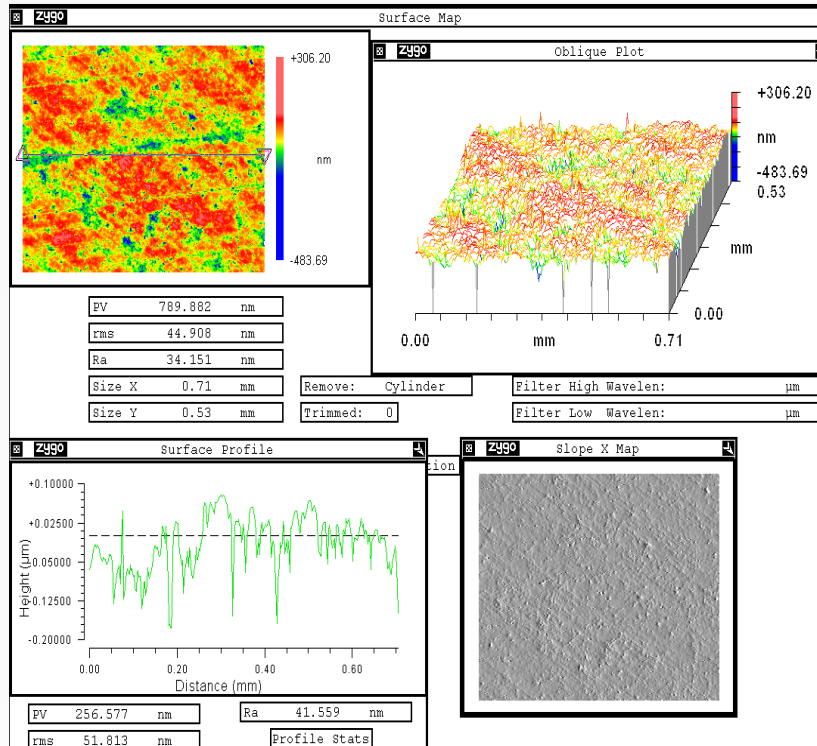
Ra 5 nm

Non Proprietary Data



# HRR Surface Finish: Zygo

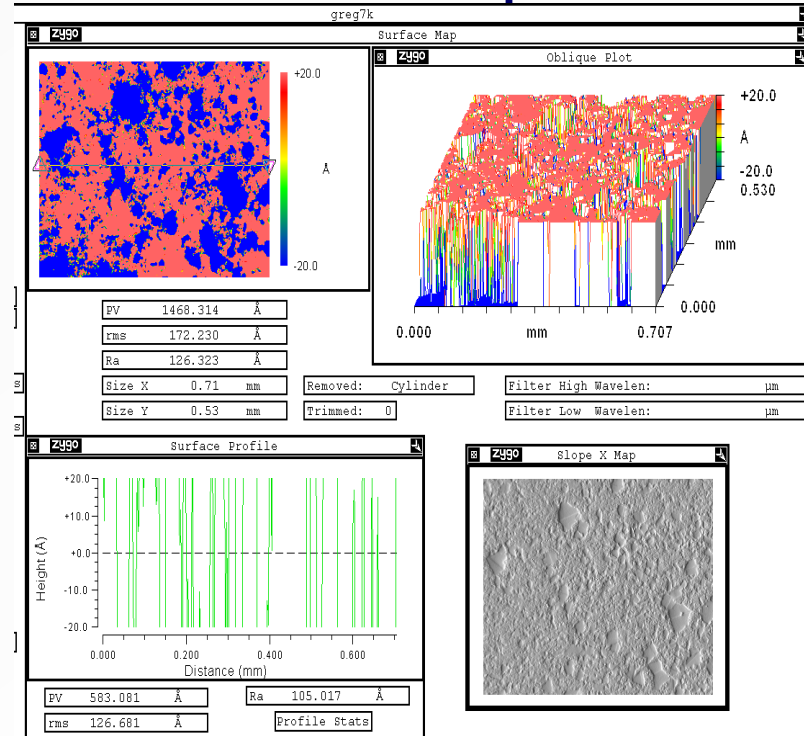
## CNC Ground



**ZYGO New View data of CNC ground surface using a 400 grit tool**

- PV = 789.9 nm
- rms = 44.9 nm

## After Sinmat HRR polish



**ZYGO New View data of CNC ground surface using a 400 grit tool**

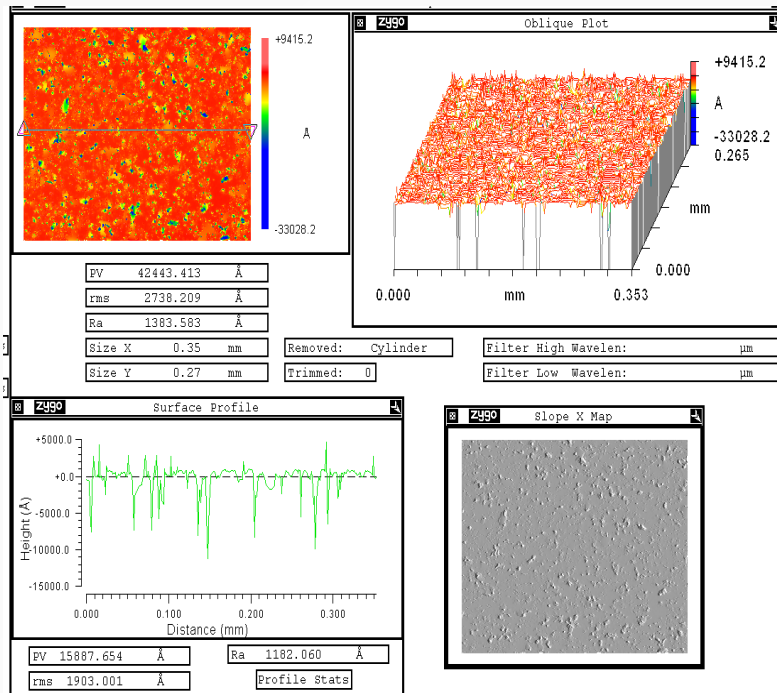
- PV = 146 nm
- rms = 12 nm

**Grain enhancement**

**Non Proprietary Data**

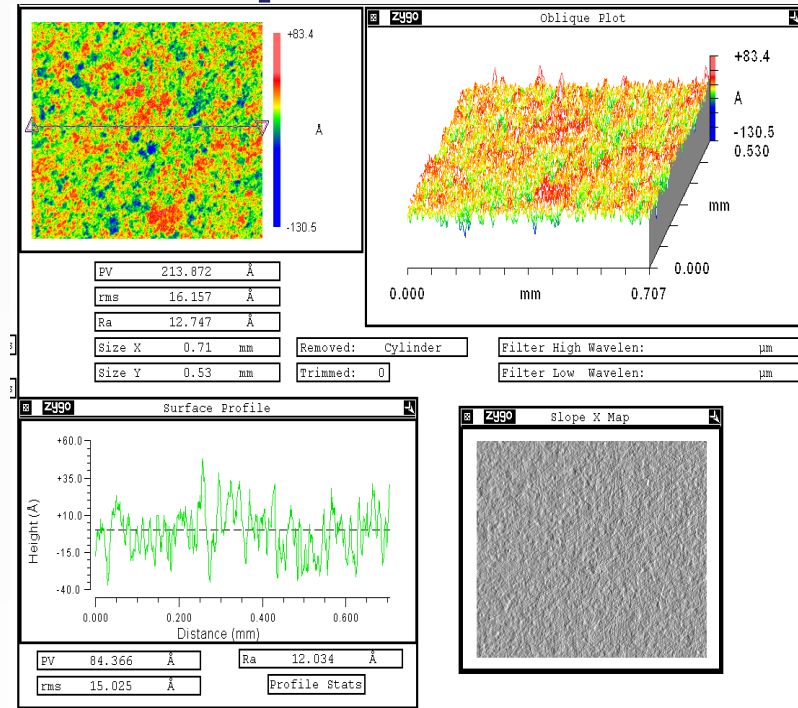
# Surface Morphology Improved HR Process- Zygo

## Before Polish



- PV = 4244 .3 nm
- rms = 273.8 nm

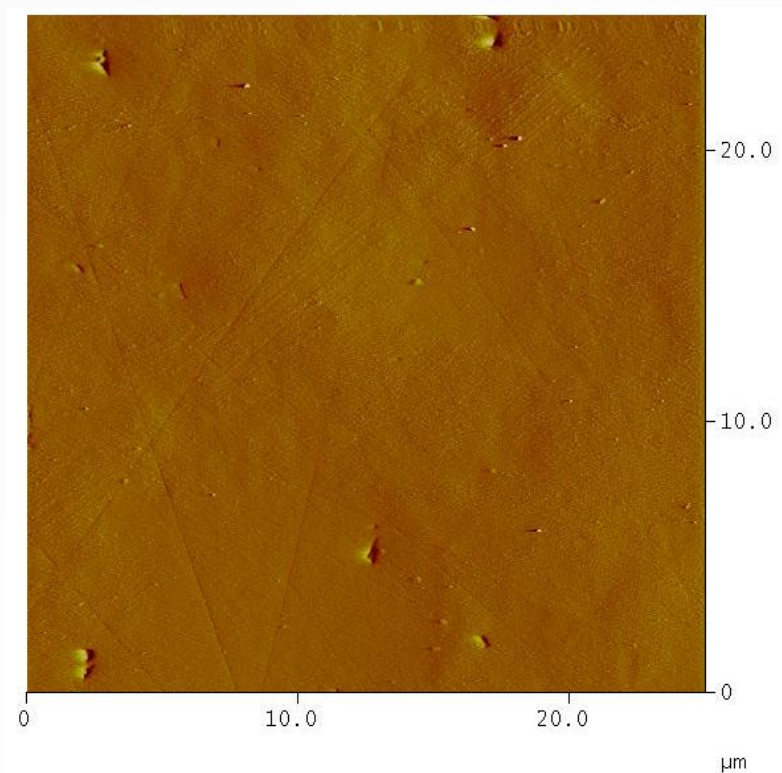
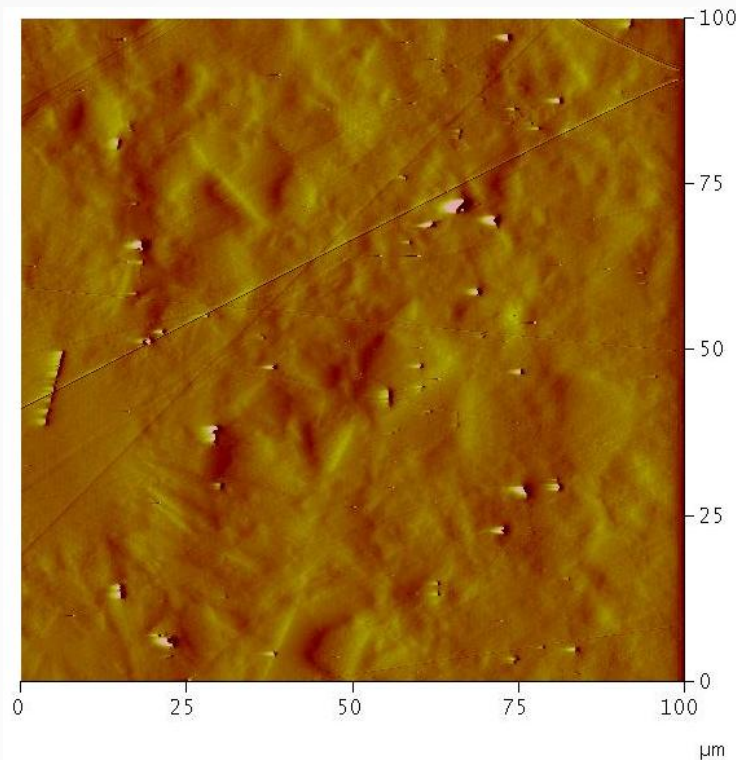
## After Improved HR Polish



- PV = 213.8 Å
- rms = 16.2 Å
- Grain highlighting is minimal

Non Proprietary Data

# Surface After HRR Polish Process AFM

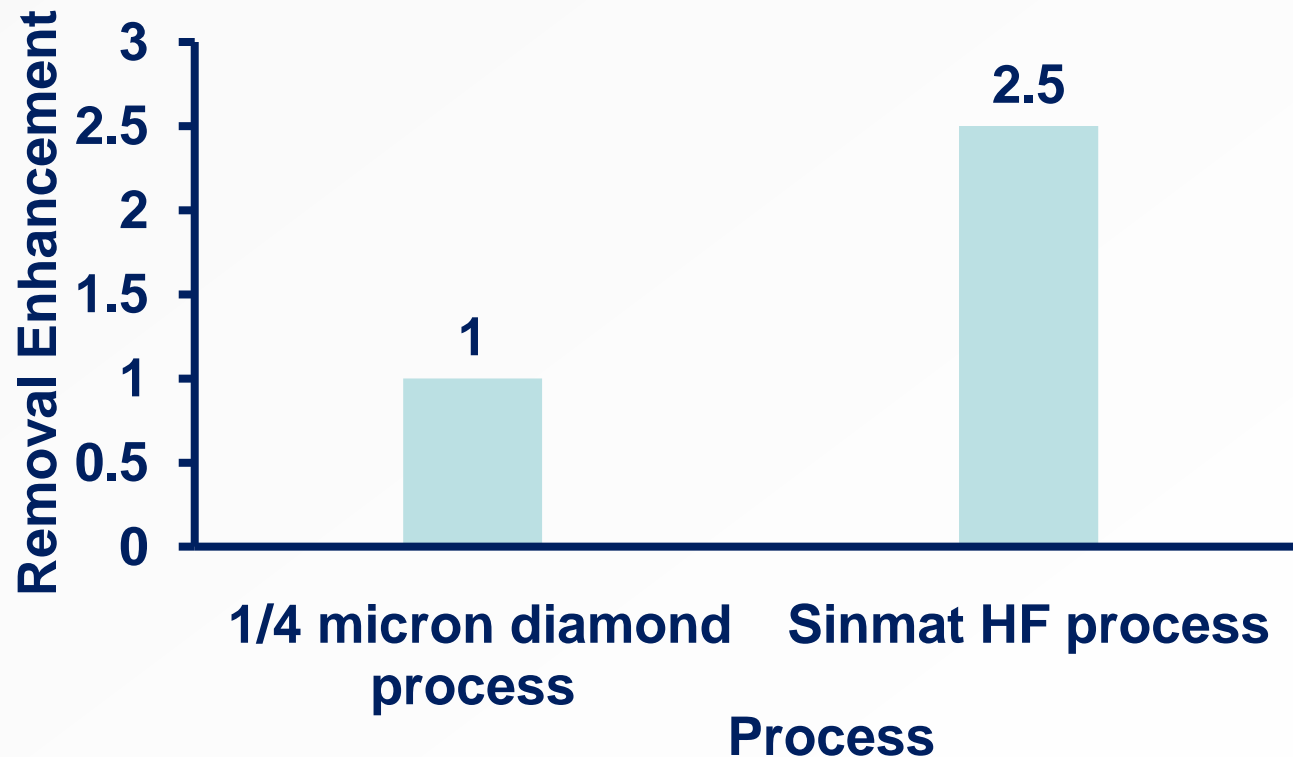


**RMS 11nm**

**Grain Highlighting, low degree of surface scratches observed**

**Non Proprietary Data**

# HF Process Polishing Rate Comparison



**2x to 3x higher removal rate**

**Non Proprietary Data**



# HF Process Wyko

## Before Polish

## After HF Polish

### Surface Statistics:

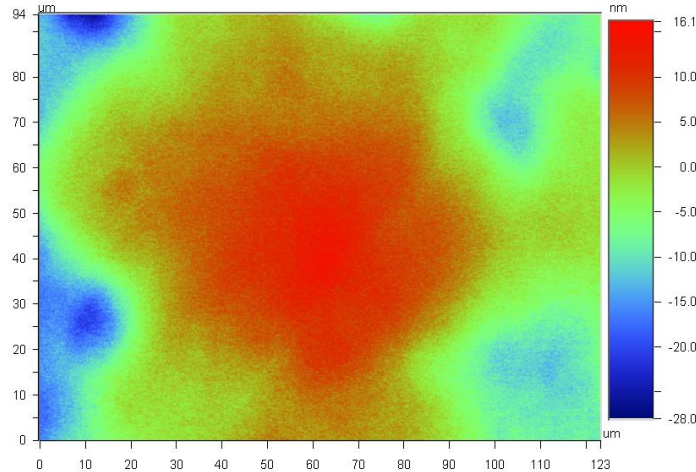
Ra: 5.87 nm  
Rq: 7.17 nm  
Rz: 41.33 nm  
Rt: 44.13 nm

### Set-up Parameters:

Size: 736 X 480  
Sampling: 167.66 nm

### Processed Options:

Terms Removed:  
Tilt  
Filtering:  
None



**Ra 6 nm**

### Surface Statistics:

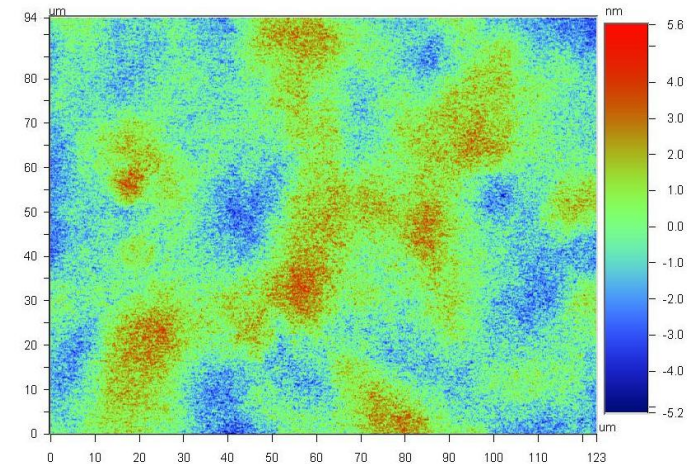
Ra: 1.04 nm  
Rq: 1.29 nm  
Rz: 9.95 nm  
Rt: 10.75 nm

### Set-up Parameters:

Size: 736 X 480  
Sampling: 167.66 nm

### Processed Options:

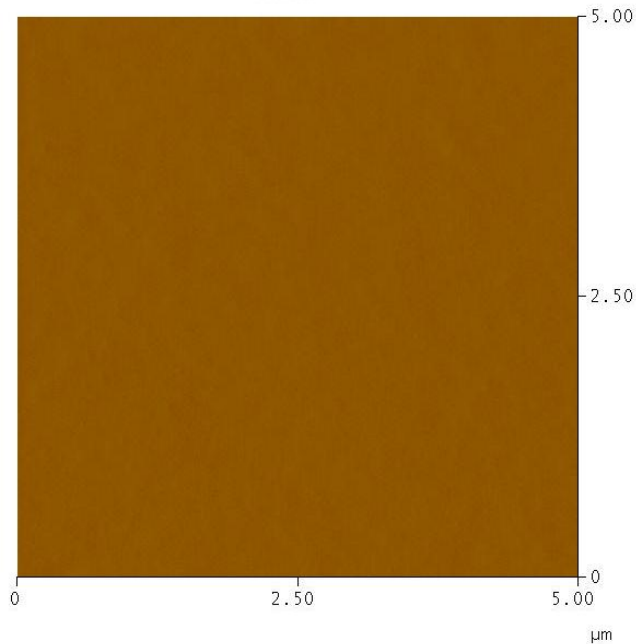
Terms Removed:  
Tilt  
Filtering:  
None



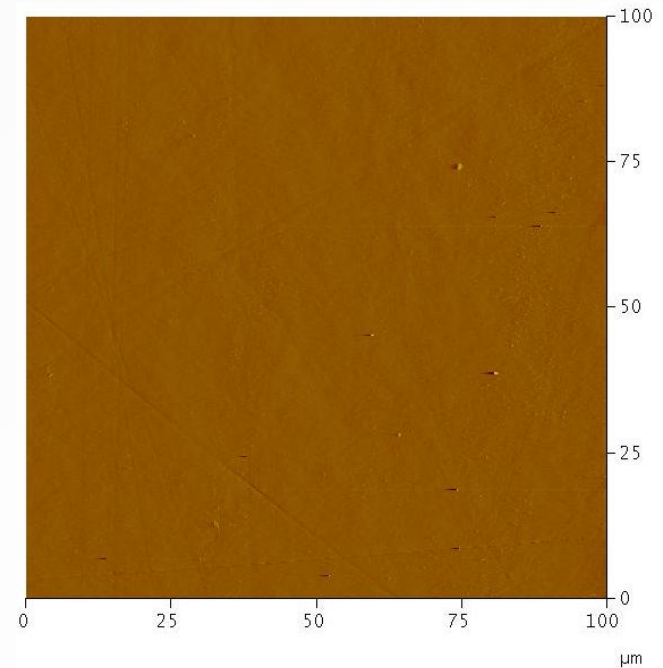
**Ra 1 nm**

**Non Proprietary Data**

# AFM Surface Finish HF Process



**5 x 5 Micron:  $R_a = 2 \text{ \AA}$**



**100 x 100 Micron:  $R_a = 18 \text{ \AA}$**

**Non Proprietary Data**

# RCMP Mirror Technology Applied to SiC Composite Material Systems

- The RCMP Technology can be used for other SiC systems (e,g Si/SiC composites)
- As RCMP is a chemically enhanced process the polishing rate selectivity between Si and SiC can be tailored
- $\text{Selectivity} = \frac{\text{Polishing Rate of SiC}}{\text{Polishing Rate of Si}}$
- Selectivity varied from approx 10 to 0.3 by controlling chemistry and particle characteristics



# Conclusion

**Two step RCMP process ie., HRR & HF process for polishing/finishing and figure correction of SiC mirrors has been developed**

- **High polish rates: upto 16X higher than base diamond particles has been achieved**
- **Excellent surface finish**
- **Low sub-surface damage**
- **High Process stability (Recirculating CMP process)**
- **Can be easily adopted with existing Equipment**
- **Substantially Reduced manufacturing cost/times**

# Current/Future Plans

- **Further Optimization of RCMP process with Penn State**
- **Fabrication of aspheric mirror**
- **Evaluation RCMP for other SiC systems (e.g Si/SiC)**
- **Work with polishing houses to integrate the RCMP technology into their process**